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Forests and the National Greenhouse Gas Inventory of Germany

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Since 1995, experiences have been gathered with the calculation of National Greenhouse Gas Inventories in Germany. Because only marginal changes of the total forested area occur in Germany, relevant changes of the balance of greenhouse gases in the forest sector are related to forest management. It was found that the increment of wood by far exceeds the harvested timber volume. Therefore, forests in Germany currently represent a significant sink for carbon (8–9 Mt $C \cdot y^{-1}$). In the context of the Kyoto Protocol, area afforested, reforested and deforested (ARD under IPCC definitions) is small. In contrast to the high quality of data from national forest inventories, reporting of ARD areas involves high error due to lacks and inconsistencies in national land-use statistics.
Keywords. Greenhouse Gas Inventory, National Forest Inventories, Germany.

1. INTRODUCTION

The importance of terrestrial ecosystems for the global carbon cycle is undoubted (IPCC, 1996). The main terrestrial compartments involved with fluxes and storage of C are vegetation and soils. In order to analyse the magnitude of sinks and sources for C in forests, the knowledge of the present distribution of C in storage compartments (pools) of vegetation and soil is necessary. The dynamics of the terrestrial C-system can only be understood, if the exchange of C between the pools is known. The German contribution derives relevant information from aggregated inventory data.

The national greenhouse gas (GHG) inventory was calculated for the years 1990 to 1994, and for 1995 to 1998. Responsible for the compilation and aggregation of inventory data on national level is the Ministry for Food, Agriculture and Forestry. Data related to national forest inventories are supplied by the Federal Institute for Forestry and Wood Products, data related to land use statistics are requested from the forest administrations of the federal states. The experiences with data compilation so far revealed the difficulty to generate an extensive and complete GHG compendium about C-balancing in forests. Now, the inventory is used:

- to carefully sort through area statistics of land-use types, and to critically review data sources and data quality,
- to aggregate data of National Forest Inventories (NFIs),
- to detect research and information gaps in the national monitoring programmes,
- to sort through aspects of forest management in the context of climate change,
- to improve and contribute to a comparable and consistent source of information in international programmes and for data comparisons.

A particular challenge lays in the quantification of error and bias about the data used. In combination with the implementation of grid point inventories, statistical quantification of error became possible. Prerequisites for the evaluations on national level are exact definitions of management categories (forest, natural regeneration, etc.) and the availability of growth- or (climatic and physiographic) eco-regions in order to regionally stratify those data.

2. RESULTS OF THE MOST RECENT UNFCCC REPORTING (2000)

2.1.Greenhouse Gas Inventory on category 5, land-use change and forestry (IPCC, 1996)

In **table 1**, an overview of C-stocks in German forests is given. All relevant C-pools that can be distinguished based on the data base for Germany, are listed. The data are aggregated to national averages although refined regional values according to tree species and age classes could also be calculated. The reference year 1990 connects the results from the IPCC reporting to the Kyoto Protocol.

Table 1. Carbon stocks in Germany's forests (1990).

C pools	Total stock ($m^3 \cdot ha^{-1}$)	Expansion factor	Conversion dry matter (t DM·m^{-3})	Calculations (t DM·ha^{-1})	(t C·ha^{-1})
Growing stock	270				
Woody biomass		1.45	0.5	195.75	97.9
above-ground		*1.20*	*0.5*	*162.00*	*81.0*
below-ground		*0.25*	*0.5*	*33.75*	*16.9*
Leaves + needles				11.0	5.5
Dead wood	6			3.0	1.5
Forest floor vegetation			0.5	1.0	0.5
Soil carbon					108.6
humus layer					*20.7*
0–30 cm					*65.2*
30–90 cm					*22.7*
Total per ha	**276**				**214.0**

Total C pool = Total per ha * forested area = $2.29*10^9$ t C. (forested area = 10.7 Mha, derived from BWI 1 and Forest Data Base)

Relevance of sector 5 for Germany. Sector 5 of the GHG Inventory deals with GHG emissions and removals from land-use change and forestry. The available data base and relevance of all worksheets for German forests was analysed and compared by Baritz (1995). From the five categories of sector 5, only category 5A "Changes in forest and other woody biomass stocks" is presently reported in Germany's GHG inventories. Details about the German contribution can be found in the internet at <www.unfccc.int/resource/docs/2000/sbsta/misc06.pdf>.

The calculations for 5A (reporting period 1990 to 1994) are presented in **table 3**. Categories 5B "Forest and grassland conversion", which includes deforestation, and 5C "Abandonment of managed land", which includes natural succession on non-forest land, are only of marginal relevance in Germany. However, because of the data requirements according to the Kyoto Protocol, such information has to be gathered for international reporting. Under 5D "CO_2 emissions and removals from soils", changes in soil C-stocks related to land-use change and to some agricultural practices, such as liming, as well as C-losses from organic soils have to be reported. No data have been made available yet. Closing actual data gaps to fulfil German reporting commitments in this area is a priority for future work. The development of an integrated inventory concept (Wolff *et al.*, 2000) as well as in depth studies on soil C (http://www.dainet.de/bfh/) will be part of this development.

Reference year. Because West and East Germany were reunified in 1990, difficulties appeared with the availability of comparable forest inventory data and area/land-use statistics (**Table 2**). Therefore, if land-use statistics are involved in the reporting, data from 1993 have been used.

Data base. (**Table 2**, **Figures 1** and **2**). Data on the present abundance of forest types by dominant tree species (**Tables 1** and **3**) originate from the National Forest Inventory (NFI, further referred as BWI "Bundeswaldinventur") in the western federal states of Germany, and the Forest Data Base (East German contribution to the BWI). BWI data are gathered from inventory points from a 4 × 4 km sampling grid (partly condensed to 2.83 × 2.83 and 2 × 2 km). The Forest Data Base consists of stand-level data from small-scale Forest Taxonomy. The BWI 1 was conducted between 1986 and 1990. Starting in 2001, BWI 2 will be conducted

– as a repetitive grid point inventory in the western federal states,
– as the first systematic inventory in the eastern federal states (total number of sampling points: 17,000).

BWI 2 will supply comparable data for all the forested land in Germany and will allow conclusions about stock changes as well as species-specific increments for the western federal states.

For the soil C-pool, an extensive study based on the Level I Forest Soil Inventory (Germany: 8 × 8 km; further referred as BZE "Bodenzustandserhebung") was conducted (methodology and results are available on line at <http://www.dainet.de/bfh/>.

While both inventories provide statistically sound data, error is mainly emerging from the use of expansion factors that have partly been derived at the end of the 19th century for the calculation, planning

Table 2. Forest inventories relevant for the greenhouse gas inventory.

Inventory	Error	Improvement
Growing stock		
National Forest Inventory (BWI) 1986-1990 *(western federal states)* grid: 4 × 4 km, partly condensed	SE area = ±1,1 % SE growing stock = ±0,8 %	BWI II *(second inventory for western federal states, first inventory for eastern federal states)* Quantification of a) biomass changes b) growth trends (increment) c) structure of timber sortiments d) eco-regional stratification (regionalization) e) stratification by age class and dominant tree
Forest Data Base *(eastern federal states)* data from small-scale field surveys of all managed forest land	regular descriptive updating of stocks and increments on the basis of yield tables at the management unit level (extrapolation error)	
Soil		
National Inventory of German Forest Soils (BZE) 1987-1993 grid: EU Level I condensed (8 × 8 km), 1800 sampling points	no fine roots	BZE II *(second inventory in all federal states)* Quantification of a) changes in carbon stocks (repeated sampling and high natural variation of humus stocks are expected to create large error) b) no improvement can be expected from Level II data (88 sampling points) c) eco-regional stratification (regionalization)
Total woody biomass		
expansion factor: default values from national data	highly inaccurate	use of data from research studies (not compiled yet)
Wood density		
conversion factor: default values from national data	appropriate for a first approach	use of updated data from research studies (not compiled yet)
Carbon content		
conversion factor: default values	seems sufficient	not necessary

and documentation of fuel wood collection in the forests. The exact quantification of wood resources in tree crowns, for example, is an important criteria for the calculation of C-sinks and sources. Therefore, future research has to be concentrated on these open questions.

According to the revised guidelines (IPCC, 1996), the role of an existing forest as a sink or source for C depends on the relationship between harvest and biomass increment. **Table 3** presents all the data and calculatory steps necessary to quantify this relationship for German forests. It can be shown that the annual increment (43.3 Mt above-ground woody biomass) exceeds the harvested timber (24.9 Mt) by 9.1 Mt $C \cdot y^{-1}$. In extension to the guidelines, a finer stratification according to tree species was possible because of the high inventory sampling density. Regional stratification and the inclusion of age classes would also be possible (with data lacking for accurate expansion factors). From the German perspective, the distinction of plantation forest and commercial forest is not attributable. Data on the consumed fuelwood and other wood use as well as on the abundance of non-forest trees are not available.

2.2. Kyoto and the German forest

According to the Kyoto Protocol Art. 3.3, "The net change in greenhouse gas emissions by sources, and removals by sinks, resulting from direct human-induced land-use change and forestry activities, limited to afforestation (A), reforestation (R) and deforestation (D) since 1990, measured as verifiable changes in C-stocks in each commitment period, shall be used to meet the commitments" of Annex I countries. Art. 3.4 provides for the inclusion of additional measures in the land use, land-use change and forestry categories. The Parties to the Kyoto Protocol were asked to provide preliminary data on ARD to the UNFCCC secretariat by 1st August 2000. In the following sections, some crucial definitions, the data base, selected results, and additional remarks are presented.

Table 3. Carbon stock changes in Germany's forests 1990–1994.

				Oak	Beech	Other broad-leaf trees, l.	Other broad-leaf trees, s.	Spruce	SilverFir	Douglas fir	Pine	Larch	Total
1	Area	ha		876,476	1,424,206	397,860	744,835	3,299,281	160.277	133.683	2,807,175	300,088	10,143,881
2	Increment	m^3 o.b.·ha^{-1}·y^{-1}	roundwood > 7cm o.b.	6.1	8.9	4.6	4.0	11.4	8.3	8.9	6.9	8.4	8.3
3	Increment	m^3 o.b.·y^{-1}	roundwood > 7cm o.b.	5,346,504	12,675,433	1,830,156	2,979,340	37,611,803	1,330,299	1,189,779	19,369,508	2,520,739	84,194,212
4	Conversion factor	m^3 o.b.·m^{-3} u.b.	roundwood > 7cm	1.511	1.273	1.499	1.559	1.278	1,082	1,362	1,317	1,512	
5				Oak	Beech and other broad-leaf trees			Spruce and other conifers			Pine and Larch		Total
6	Increment	m^3 o.b.·y^{-1}	roundwood > 7cm o.b.	5,346,504		17,484,929			40,131,881			21,890,247	84,853,561
7	Expansion factor	total a.g. wood volume/wood > 7 cm		1.24		1.24			1.14			1.14	
8	Increment	m^3 o.b.·y^{-1}	above-ground wood volume	6,629,664		21,681,312			45,750,345			24,954,881	99,016,203
9	Conversion factor	t·m^{-3}	above-ground woody biomass	0.56		0.55			0.37			0.43	
10	Increment	t·y^{-1}	above-ground woody biomass	3,712,612		11,924,722			16,927,627			10,730,599	43,295,560
11	Harvest	m^3 u.b.·y^{-1}	roundwood > 7cm u.b.	1,086,200		6,161,000			25,930,400			6,380,600	39,558,200
12	Conversion factor	m^3 o.b.·m^{-3} u.b.	roundwood > 7cm	1,511		1,345			1,274			1,339	
13	Harvest	m^3 o.b.·y^{-1}	roundwood > 7cm o.b.	1,641,247		8,289,612			33,043,390			8,545,446	51,519,695
14	Harvest	m^3 o.b.·y^{-1}	above-ground wood volume	2,035,146		10,279,118			37,669,465			9,741,808	59,725,538
15	Harvest	t·y^{-1}	above-ground woody biomass	1,139,682		5,653,515			13,937,702			4,188,978	24,919,876
16	Stock Change	t·y^{-1}	above-ground woody biomass	2,572,930		6,271,207			2,989,925			6,541,621	18,375,684
17	Stock Change	t·y^{-1}·ha^{-1}	above-ground woody biomass	2.9		2.4			0.8			2.1	1.8
18	Proportion of C in biomass			50%		50%			50%			50%	
19	C-Stock Change	t·y^{-1}	C in a.g. woody biomass	1,286,465		3,135,603			1,494,963			3,270,811	9,187,842
20	CO_2-Sequestration	3.67 CO_2/C	t CO_2·y^{-1}	4,721,327		11,507,664			5,486,513			12,003,875	33,719,380

Explanatory notes to table3 = FCCC/SBSTA/2000/misc, 6 (on line at: <http://www.unfccc.de>); o.b. = over bark;u.b. = under bark.

Figure 1. Map of the Bundeswaldinventur (BWI) grid.

Figure 2. Map of the Bodenzustandserhebung (BZE) grid.

Definitions.

– *Forest*: based on German forest legislation is defined as an "area of land stocked with forest plants, including clearings, forest roads, gaps in the forest cover, forest meadows, timber yards and other areas connected with forest. Smaller patches with small clusters of trees in midst farmland or settlements are not counted as forest".
– *Deforestation*: was defined as the "conversion of forest to another land use".
– *Afforestation* was defined as the "establishment of forest on non-forest land".
– *Reforestation*:
  •Reforestation under the IPCC definition is associated with land-use change (in the data submission, it is included under afforestation).
  • Reforestation under the FAO-definition includes post-harvest regeneration.

Data base and assumptions. Data for the ARD calculations were derived from different sources: the Laender (federal states) provided aggregated data on the areas deforested and afforested since 1990. An estimate of reforestation under the FAO-definition has been drawn from TBFRA 2000 (FAO, 1997). Estimates of the C-stocks have been derived from average data as shown in **table 1**. The annual C-uptake by regrowing young stands from afforestation and reforestation was estimated to 1.5 ± 0.5 t C·ha^{-1}·y^{-1}. This relatively low uptake reflects the high share of slowly growing broad-leaved trees used for afforestation and reforestation in Germany.

Accounting scenarios and national results. Four accounting scenarios as described in the LULUCF-SR (2000) have been examined, one under the IPCC definition of afforestation and reforestation, and three under the FAO definition. For details, refer to Table 3-17, p. 174-175 (*ibidem*). Each of the scenarios supplies completely different results as shown in **figure 3**. Under the IPCC definition, "reforestation" and "afforestation" are treated together; existing data do not allow to separate them. Under "FAO Activity-based", the accounting begins with the onset of the activity of "reforestation"; only C-stock changes in growing young stands planted post-harvest are counted. Under "FAO Land-based II" the delayed decay of slash post-harvest during the commitment period is counted in addition to changes in the growing stock of the young stand. Under "FAO Land-based I", all stock changes during the commitment period occurring on lands, which were reforested since 1990, are counted. Under this scenario, a big net source results due to the inclusion of harvest during the commitment period.

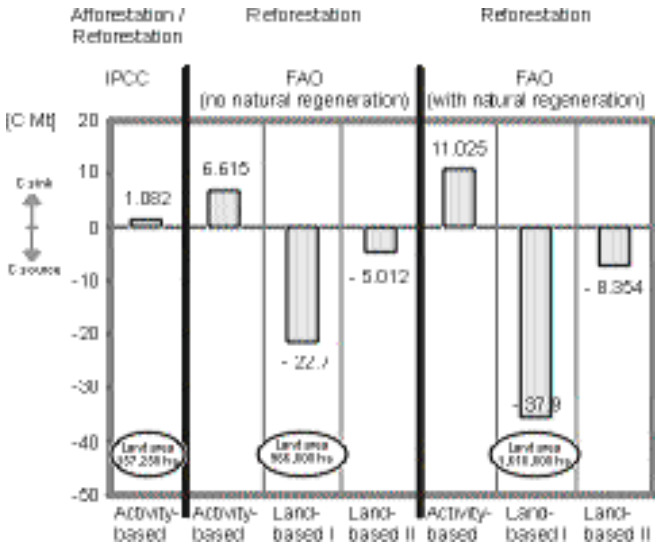

Figure 3. Projected area and carbon stock change for the commitment period (1990–2012) for reforestation, calculated with different accounting strategies.

Future developments. Besides problems with different accounting strategies, the inclusion of additional activities under Art. 3.4 was an important issue at the sixth Conference of the Parties in The Hague. It is the political position of Germany, that emphasis must be primarily given to emissions reductions. Improvements are needed for both, the IPCC Reporting Guidelines (e.g. on the importance of wood products) and Germany's national inventory system (e.g. on soil C-dynamics, and on expansion factors). Area-based information on land use is critical for a complete inventory system, particularly in the context of the Kyoto Protocol (ARD area).

Bibliography

Baritz R. (1995). *Stellungnahme zu den Defaultwerten und Datenherleitung im IPCC-Treibhausgas-Inventar. Bundesforschungsanstalt für Forst- und Holzwirtschaft, Hamburg und Eberswalde*.

IPCC (1996). *Revised 1996 IPCC guidelines for greenhouse gas inventories*. Bracknell: UK Meteorological Office.

LULUCF-SR (2000). *Special report of the IPCC on land use, land-use change, and forestry*. Cambridge, UK: Cambridge University Press.

FAO (1997). *Temperate and boreal forest resources assessment 2000*. Rome: FAO, 1997.

Wolff B., Riek W., Baritz R. (2000). *Ansätze für die bundesweite Klassifizierung und Regionalisierung von Waldbodendaten*. (UBA-texte; 49/00).

(5 ref.) Manuscript received 2 November 2000